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OPPORTUNITIES AND CHALLENGES OF SUSTAINABLE ENERGY TECHNOLOGY IN RURAL FIJI

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Abstract

This study examines the opportunity and scope for choosing a renewable energy supply system for remote communities of Fiji and provides mechanisms to help these communities to use available local renewable energy sources to reduce the impact of energy poverty. The study has used data from secondary sources such as government documents of Fiji, Fiji Bureau of Statistics, and statistics published by other agencies. We have assessed the appropriateness of the energy supply systems on the basis of certain criteria: availability of resources, complexity of technology, cost effectiveness, matching supply with demand, contribution to GHG (Green House Gas) reduction and major constraints, if any. The study found that most of the technologies have advantages as well as disadvantages. Using these factors, the study introduces a model for assessing different sources of energy for implementation readiness. The study concludes that no single source is currently appropriate for the rural area of Fiji. Rather a combination of sources may furnish optimal output in meeting the energy needs. Findings of the study should be of interest to policy makers and researchers.

Key Words: *Sustainable Energy Technology, Renewable Energy Resources, Energy Requirement Assessment.*

1. INTRODUCTION

Human resources, physical resources and energy resources dominate the major processes within a business. The demand ratios of each of these resources are unique for each of the organizations and it also reflects the environmental factors that the businesses run in and the process efficiencies within the organizations. It is important to realize the uniqueness of the demands and strategise accordingly to establish a sustainable growth model in any business environment. The paper examines the opportunity and scope for choosing a renewable energy supply system for remote

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communities of Fiji and provide mechanisms to help these communities to use available local renewable energy sources to reduce the impact of energy poverty and hence promote small business entrepreneurship.

A good number of studies have been carried out on renewable energy and their implications in Fiji but most of them are focused on reporting the status of renewable energy uses, technological availability and the future demand for energy (Ali, 2010; 2006; ESCAP, 2010; Trading economics, 2008; Fiji climate lab, 2010; Haszler, H. et. Al. 2009; Reddy & Naidu, 2001). However, issues like the long term sustainability and opportunity cost of resources, economic and technical ability of users and the appropriateness of the supply system with the nature of needs, have not been addressed. This paper aims to fill that gap. It is envisaged that the findings of this paper may be of interest to policy makers, researchers and development practitioners.

The structure of the paper is as follows. Section 2 presents an overview of the energy resources in Fiji while Section 3 describes the chosen technology justification criteria. Application of justification criteria has been discussed in Sections 4 and 5, followed by conclusion in Section 6.

2. ENERGY OVERVIEW

Fiji consists of more than 320 islands of which only one third are inhabited. Approximately 90% of the nation's 837,271 people live on the two main islands (Viti Levu & Vanua Levu) that cover nearly 85% of the total land area. About 200,000 people in the rural sector do not have electricity services (Census 2007).

Fiji has a major hydroelectric scheme (Monasavu) that serves the bulk of the population on the main island of Viti Levu. *Bagasse,* a by product of sugarcane, and wood wastes from saw mills, are used for power generation. Firewood remains the leading fuel for domestic cooking. Thus 73% of the energy supply is from domestic sources. In 2008, there was an average mix of 62.1% of electricity with hydropower, with 33.8% of the balance coming from imported petroleum products, with 0.6% from wind generated sources and 3.5% from independent power producers (ESCAP, 2010).

2.1 Renewable Energy Resources (RERs)

Fiji has abundance of energy resources that include biomass, solar, hydro, wind and geothermal.

a) Hydro

Due to the prolonged drought on the western part of Viti Levu, the Monasavu hydropower plant had been supplying approximately about 35% of Fiji's electricity needs. There are several additional sites at a scale of 5 to over 50 MW, which have the potential to be major suppliers. With a potential capacity of generating 300 MW, hydropower is likely to provide the bulk of electricity over the next several decades. Chinese, Korean and Turkish funding has led to the development of these hydro sites.

b) Biomass

The biomass resource supplies approximately 64% of the energy consumed in Fiji. Rural households use firewood for domestic cooking. There is also some trade in firewood in urban areas. Coconut residues are also used for copra drying. The bulk of the *bagasse* (93%) available at the sugar mills is used to produce the heat and electricity for internal use. For example, in 1999, 3% of the electricity consumed in Fiji was produced by using bagasse.

c) Geothermal

There is some evidence of the presence of geothermal resources (hot rocks) on the two major islands. Preliminary assessments by FDOE indicate that there is potential for steam generation and electricity production at two sites in Labasa and Savusavu.

d) Solar

The solar resource was estimated through correlating solar-radiation-satellite data to ground data obtained by pyronometers. The satellite data provide global coverage on equal area cells (= 280 km x 280 km). These cells cover areas that are larger than the islands that encompass Fiji. A correction factor of 0.9 to 0.8 is required to correlate annual averages and monthly distribution of satellite data with ground data available for specific sites. At the conceptual design level, insolation throughout Fiji can be defined as ranging from 80 % to 100 % of the values derived from the satellite record. The total installed PV (Photo Voltaic) capacity in Fiji is about 80 KW.

e) Wind

FDOE (Fijian Department Of Energy) has pursued evaluation of wind resources in several locations. Unfortunately, the resource required for commercial development has not yet been fully identified. Wind regimes require annual averages of at least 7 m/s to produce electricity at rates that are competitive with those available through the national grid. A value of approximately 6 m/s is cost competitive for rural electrification in remote locations. The Nabouwalu hybrid system includes eight wind-turbine-generators amounting to an installed (wind) capacity of approximately 70 KW. This wind resource corresponds to an annual average speed of 6.2 m/s. The FDOE has taken the initiative to install a similar system in other appropriate sites. Another one is the Vutuni wind farm in Sigatoka, which is connected to the national grid.

3. HYPOTHESIS OF THE STUDY

Justifying a Sustainable Energy Technology involves a complex decision depending upon various factors influencing this decision.

The appropriateness of an individual technology or its application might be justified by a multidimensional approach because of diversified uses and applications of the technology. Hence the selection criteria might also be different from one perspective to another. For instance, a particular type of technology might be suitable from suppliers' point of view while that might not be justified from the buyers' point of interest. Accordingly, selection criteria from suppliers' part would definitely be different from those of buyers. Therefore, it is worth while to assess technology choice based on the users' economic ability, technical capability, social attitudes and the ability of that technology to perform the desired tasks. This is more crucial while assessing SET for a rural community.

It is arguable that recipients' cultural and religious issues are also vital factors for assessing the suitability of a particular technology for a specific community. This is logical because if a technology is chosen for a society where it does not match with users' cultural and religious sentiments, then users might not be willing to participate in implementing that technology, or they might not use that technology at all. Ultimately the process of choosing a particular technology would be ineffective. An evidence of this nature can be seen in Ali (2005), where it has been shown that the biogas program in the Muslim community of Indonesia failed because the use of pig dung was not perceived as a valuable input raw material in the biogas plants. On the other hand, similar biogas plants have been successful in China.

Therefore, to assess SET from the users' end, the criteria for justifying the appropriateness of the proposed SET is hypothesized as follows: (a) Availability of a resource base: How much resources would be available to supply a particular energy and what are its long-term consequences? (b) Degree of technological complexity. This implies whether rural population would be able to adopt a particular technology with their technical knowledge. (c) Cost effectiveness. This indicates that the cost of production and distribution of a particular type of energy would be within the reach of those who can afford it in the rural community. (d) Balancing between supply and pattern of needs. This highlights whether that technology can supply a particular type of energy that the users need to use and (e) whether the contribution of a particular energy technology would reduce the GHG emission.

Therefore, from the above discussion we propose the following model **(Figure-2.1)** in justifying a source of energy decision.

In the following sections of this paper, we attempt to apply this model to test the feasibility of Renewable Energy Resources (RERs) from two different sources, namely, biomass and solar.

4. NATURE OF ENERGY NEED IN RURAL FIJI

The purpose of this section is to illustrate the pattern of energy consumption in the rural community of Fiji. The information and analysis of this section would be useful to match the technological suitability with the users' requirements. An attempt needs to be made to determine the approximate range of demand for a particular activity. To do this, wherever possible, an approximate demand would also be estimated.

The categorization of energy use pattern in rural Fiji needs careful assessment. It is seen in some literature that they have categorized rural energy consumption pattern into four groups like consumption in households, consumption in commercial units, consumption in agriculture and consumption in rural industry (Ali, 2006). Although this type of grouping seems logical, the problem associated with this is that it is hard to separate the energy used for the industry from the energy used for households. One of the examples is that biomass is used as fuel for processing food for sale. It is quite common in rural Fiji that in processing food for commercial purposes, household cooking activities are also done in the same burner. To avoid this complexity, this paper has analyzed energy consumption patterns generally under two categories: household consumption and commercial consumption.

4.1 Energy for Households

In a rural community, household sector consumes the largest share of energy (Ali, 2005; 2006). Agriculture is an important productive sector and will continue to require increasing inputs of energy for use of fertilizer, irrigation, machinery and transportation, so as to ensure a higher yield of food and cash crops. Biomass fuel is mainly used in industries for the processing of agricultural crops such as paddy boiling for producing parboiled rice. Industrial activities in the rural areas are at present limited but are expected to grow in future and thus it will need more energy. There is a growing trend of using fossil fuel in transport sector in rural areas such as the use of mechanized small vehicles. However, considering the need and importance of SET and the scope of this investigation, this paper excludes these issues from the analysis.

4.2 Cooking in Rural Households

It has already been mentioned that in the rural Fiji, household activities, mostly cooking, consume the lion's share of available energy. In some developing countries (e.g. Bangladesh), people utilize mostly biomass for cooking their foods (almost 100 percent in rural households and 70 percent in urban households, ADB, 2000). Different types of biomass fuels are used as cooking fuels. Based on our analysis of demand as a dynamic concept, although issues like how much energy is consumed per household and how much is consumed per person are important for analyzing demands, due to a limited scope, this study could not undertake those tasks in detail. However, based on some studies, it is said that the per capita biomass fuel consumption is 4.44GJ/year (Ali 2002; 2005; 2006).

4.3 Household Lighting

In rural Fiji, 90.47 percent households use kerosene for lighting while 9.53 percent gets light from other sources including electricity. The total consumption of energy for lighting in rural Fiji depends on the number of households, number of rooms per household, number of lights used per room and the duration of lighting per night. Overall kerosene contributes to 0.08 percent of total energy consumption in Fiji (Singh, 2009 p.144).

The pattern of energy consumption by different sectors in Fiji is presented in **Table-1**.

Table-1 shows that 31.2 percent of total energy is consumed by the household sector while 43.4 percent is consumed by the commercial sector. This means that the demand for energy in the commercial sector is large. The expansion of commercial activities will create a larger demand in future.

4.4 Energy Demand in Agriculture

Agriculture is the predominant sector of the Fijian Economy. Most of the rural population of Fiji depend on agriculture for survival. We have mentioned earlier that agricultural sector of Fiji is still at a traditional stage initiated, although maximum efforts have been to move agriculture from traditional to semi-mechanized stage, where the need for particular type of energy arises. While the thrust of this study is to deal with energy needs related to small business in rural Fiji, it is worthwhile to discuss briefly the nature of energy consumption in the agriculture sector.

The types and amount of energy consumed in the agricultural production varies from crop to crop, season to season, and even location to location. In Fiji, energy sources that are directly used for agricultural production are: i) human and animal muscle power; ii) human labor; iii) diesel fuel and electricity for irrigation; and iv) energy in the form of heat and mechanical power.

In Fiji, irrigation in the agricultural sector started in the mid sixties. Two types of irrigation devices are available: manual and power operated. The available power driven irrigation devices are low lift pumps, shallow tube well, deep tube well and submersible pumps. Diesel or electricity powers them. The traditional devices are manually operated and its output is much lower than those from modern devices.

5.0 AVAILABILITY OF BIOMASS FOR ENERGY

In Fiji, sources of biomass for energy are agricultural residues, wood fuels (firewood, tree residues), *baggase* and coconut residues. Forestry is the main source of firewood supply. The forest sector, on an average, accounts for 1.2% of GDP and 4.1% of export earnings. Fiji has a total forest cover of 1,054,419 hectares, covering 58% of the total land area. This consists of 899,229 hectares of native forest, 116,488 hectares of plantation forest (52,419 hectares of hardwood plantations and 64,068 hectares of softwood plantations) and 38,742 hectares of mangrove forest. The native forest consists of 5,738 hectares of nature reserves, 16,109 hectares of forest reserves, and 1,300 hectares of recreational parks (ESCAP, 2010, p. 30-32).

The performance of the forestry sector in the past few years has been poor and it declined by 1.6% in 2007, 3.4% in 2008 and was projected to have a fall in 2009 by 9.1%

mainly due to reduced woodchips exports which, based on current orders, is projected to fall by 43.8%. However, a recovery of 4.3% and 0.9% is currently projected for 2010 and 2011 respectively, as Government puts in place measures to address the current institutional constraints (ibid).

Total wood production in Fiji is presently approaching 500,000 cubic metres annually with 100,000 cubic metres from native forests, 100,000 cubic metres from mahogany plantations, and 300,000 cubic metres from pine plantations. Fiji has a total of 41,000 hectares of mahogany stocking which is one of the largest mature mahogany resources in the world. There is potential for the large denuded forest grasslands to be converted into forest plantations of sandalwood (*Santalum yasi*) and teak (*Tectona grandis*) plantations. Reforestation could result in the employment of skilled and unskilled people who have been displaced from the sugar industry. Sugarcane is the source of *baggase* supply. It is seen that sugar production has been on a decreasing trend over the years and this decline could be traced to 1997. It used to be a major export commodity, accounting for around 21% of total exports in the period 1998 – 2001. The industry had provided employment to about 100,000 people, ranging from farmers to mill workers. With the decrease in production, the Fiji Sugar Corporation has been facing annual losses yearly. Similarly the ability of the mill to provide electricity from *baggase* has also been affected.

Coconut oil is also used as an alternative to diesel fuel to operate diesel generators at two FDOE pilot projects in rural locations: (i) 80 KVA generator supports 198 households in three villages in Vanuabalavu, Lau since May 2000 and (ii) 45 KVA generator installed in July 2001 for 60 households in Welagi, Taveuni. Preliminary indications are that the technology is viable but there are difficulties with the expertise of locals for the overall running of operations and in the production of copra oil (fuel).With the recent intentions of the Government, bio diesel plants will now be installed in copra producing communities.

Furthermore, the first question is, how to increase forestry cultivation and the supply of biomass from forests. In Fiji, total available arable land area was 0.18 million hectares in 1997 (23.4% of total land) which had decreased to 0.17 million hectares in 2007 (Trading Economics, 2010). This means that about 5 percent cultivable land had decreased in the last 10 years. Moreover, because of projected increase population in future, the need of land for other uses such as housing, roads etc. will reduce the amount of cultivable land much more quickly. Currently, per capita land is 0.2 hectare, which is not sustainable in the distant future (Trading Economics, 2010). There is no alternative to increasing the operational land areas without deforestation.

Based on the above analysis, the following remarks are submitted: (a) the projected demand for biomass fuels increases at a higher rate than the projected supply, resulting in a considerable deficit. This deficit will have to be met either by substituting fossil fuel and/or by an appropriate rural energy development programme like solar and wind power, (b) if no policy intervention is undertaken to meet the fuel deficit, people will have no other choice but to meet the demand by further utilizing tree resources.

5.1 Technological Complexity of Biomass Energy

The degree of technological complexity of biomass technology depends on the type of inputs used. For example, the technology of the use of biomass for producing ethanol for transport is more complex than that of using biomass for producing biogas for cooking. However, the most common methods and techniques of biomass uses are direct burning in a fireplace, pyrolysis, briquetting, charcoal making, biogas plants, dung cake etc. In rural Fiji, most of the agricultural and forest residues are burned directly in a fireplace. The machinery and equipment, necessary for processing biomass into a useable and efficient form, are available in the local markets.

5.2 Cost Effectiveness of Biomass Technology

The cost effectiveness of biomass technology depends on the type of biomass used, type of technology used and the purpose for which it is used. For example, if crop residues are directly (unprocessed) used for cooking purposes, then the cost of that fuel will be very insignificant because there will be no cost for processing these residues. Similarly, if residues are used to produce biogas and if this is used as energy, then this will be more expensive than those original residues because the production of biogas incurs cost for equipments, labor etc. Biomass can be used as fuel mainly, apart from direct burning, in the form of biogas, charcoal, dung cake, dung stick etc. These different forms of energy incur different types of costs.

5.3 Matching Demand with Supply

Rural people of Fiji have been using biomass as a source of fuel since ancient times. They use biomass to meet their energy needs of household activities and for some commercial activities. However, biomass cannot be used for lighting until some sort of technology is invented. Households, especially in islands, use kerosene for lighting as there are no alternative sources of energy for lighting and no electricity supply in their localities. This scenario indicates that people are interested in shifting their energy consumption patterns for lighting. Therefore, the supply of biomass energy will be able to satisfy a large part of its demand.

5.4 Contribution to Greenhouse Gas (GHG) Reduction

The contribution of biomass to reduction of GHG emission is twofold. First, the use of biomass as energy emits gases to the atmosphere (but less than that of fossil fuel), which ultimately increases the volume of GHG in the ozone layer. Second, trees take in CO_2 from the atmosphere, which ultimately reduces the volume of GHG in the atmosphere. In fact, the contribution of biomass in the GHG emission is subject to a recycling process. However, the quantity of absorption and emission depends on the extent of deforestation and re-forestation. However, in Fiji, the estimated volume of CO_2 released from fossil fuel was 1.6 megatons, which accounted for 2.2 tons CO_2 per person in this year (Fiji Climatelab, 2007).

5.5 Major Constraints of Biomass Technology

It is seen that availability of biomass is directly related to availability of land, which is getting scarcer in Fiji. Presently the area of per capita cultivable land is only 0.2 hectare. Hence the question arises as to whether this land will be used for planting of trees or for food crops (Trading Economics 2010).

6. FEASIBILITY OF SOLAR ENERGY

The feasibility of solar energy technology in terms of the justification criteria such as availability of supply, technological complexity, cost effectiveness, matching with demand, contribution towards GHG emission reduction and major constraints (if any) will be examined in this section.

6.1 Availability of Solar Radiation

The raw material required for solar energy is basically solar radiation, which is abundant in Fiji. This is particularly abundant in Fiji because geographically the country is located between the longitude of 178° W and 174° E and between 15 degree and 22 degree S latitude in the globe. Solar radiation that falls in Fiji annually has been estimated to be nearly 600 times the total energy consumption of 285 PJ that is obtained from traditional and commercial sources. The long term average sunshine data indicates that the period of bright (more than 200 watts/ sq.m intensity) sunshine hours in the coastal region varies from 3 to 11 hours daily. The global radiation varies from 3.8 kwh/sq.m/day to 6.4 kwh/sq.m/day. These data indicate that there are good prospects for solar thermal and photovoltaic application in Fiji.

6.2 Technological Complexity of Solar Energy

Generally, the degree of complexity of an energy technology depends on the type of technology used. For example, there are two technologies in use for solar energy. One is solar photovoltaic system for lighting and another is solar dryer for drying purposes. The technological complexity of the photovoltaic system is higher than that of the dryer. This is because photovoltaic system needs high skilled-trained manpower for its repairs and maintenance in comparison to the dryer system. However, the complexity in terms of operating them is almost equal for both devices. Users need minimum training for operating both the devices.

6.3 Cost Effectiveness of Solar Energy

The cost effectiveness of a particular energy technology involves the calculation of costs of raw materials, cost of machinery and equipment, labor costs, management costs and costs of some other utilities. The cost of producing one unit of energy is measured to see whether any particular type of energy technology is worthy to be used.

The fact is that spare parts and all types of machinery and equipment of solar power come from foreign countries. Therefore, the actual cost of a complete plant is hard to estimate. However, a few organizations in public sector and also some non-government organizations are working on disseminating this technology. It is noteworthy to see the range of costing of some organizations involved with solar energy in Fiji. In one case, the average cost per plant is F$ 5000 and the Government of New Zealand has been supporting this scheme since 2004.

Solar power technology produces energy in the form of direct heat and in the form of electricity (e.g. for lighting purposes). Activities like cooking, lighting, entertainment, drying etc, either in the households or in the commercial enterprises, can be done with the solar energy. At present, rural population of Fiji use mostly biomass which is used in the open stove. For the use of solar energy for doing similar activities (e.g. cooking), they will have to modify their stoves (solar cooker). Additionally, the matching of demand with the supply of solar energy for the rural community of Fiji, might encourage adoption of new devices such as solar cooker, dryer, and so forth. Solar energy is environment friendly. Solar energy technology is free from environmental pollution because it does not use any fossil fuel which is harmful to the environment. Further, it does not release any GHG such as CO_2.

6.4 Major Constraints of Solar Energy Technology

The major constraints in the transfer of solar energy technology in rural Fiji are capital and knowledge. Money and knowledge are required for the sustainable energy technology transfer processes. What will be the form of transfer of capital or technical knowhow needs further indepth investigation.

7. CONCLUSION

Fiji is suffering from acute shortage of energy. The gap between demand and supply is gradually increasing. Although it has some reserves of energy resources, due to economic and technical inability, it encounters obstacles in delivering energy supply network to the door of rural population. The dependence on imported fuels is gradually increasing and the rural population is largely disadvantaged due to their low purchasing power.

In rural Fiji, the major demand for energy in the household sector is for cooking and for lighting purposes. In the commercial sector, the demand is engendered by small businesses, irrigation systems in agriculture and in crop processing. Based on the current and potential consumption patterns, economic abilities and technical capabilities, some criteria were chosen to examine the feasibility of introducing SET to rural Fiji. Availability of resources, degree of technological complexity, cost effectiveness of technology, matching demand with supply, contribution to GHG reduction were the major constraints. Three energy technologies, namely: Biomass, Solar and Wind Power were examined to find out the best possible option for the rural Fiji.

The model used to analyze the energy resources could be reused for assessing other sources of energy. However, having analyzed the energy use patterns, energy sources and costs versus benefits of potential forms of sustainable energy, it appears that neither of the technologies (biomass or solar) considered in this Paper would be fully implementable in isolation in rural Fiji. A combination of biomass, solar and energy sources is recommended as being appropriate. Further analyses of other resources may result in the development of an optimal energy resource for this country.

Finally, as the Paper has analysed data from the conceptual point of view, its implication might be limited to the policy level. Further investigation on cost benefit quantification might increase the utility of the Paper.

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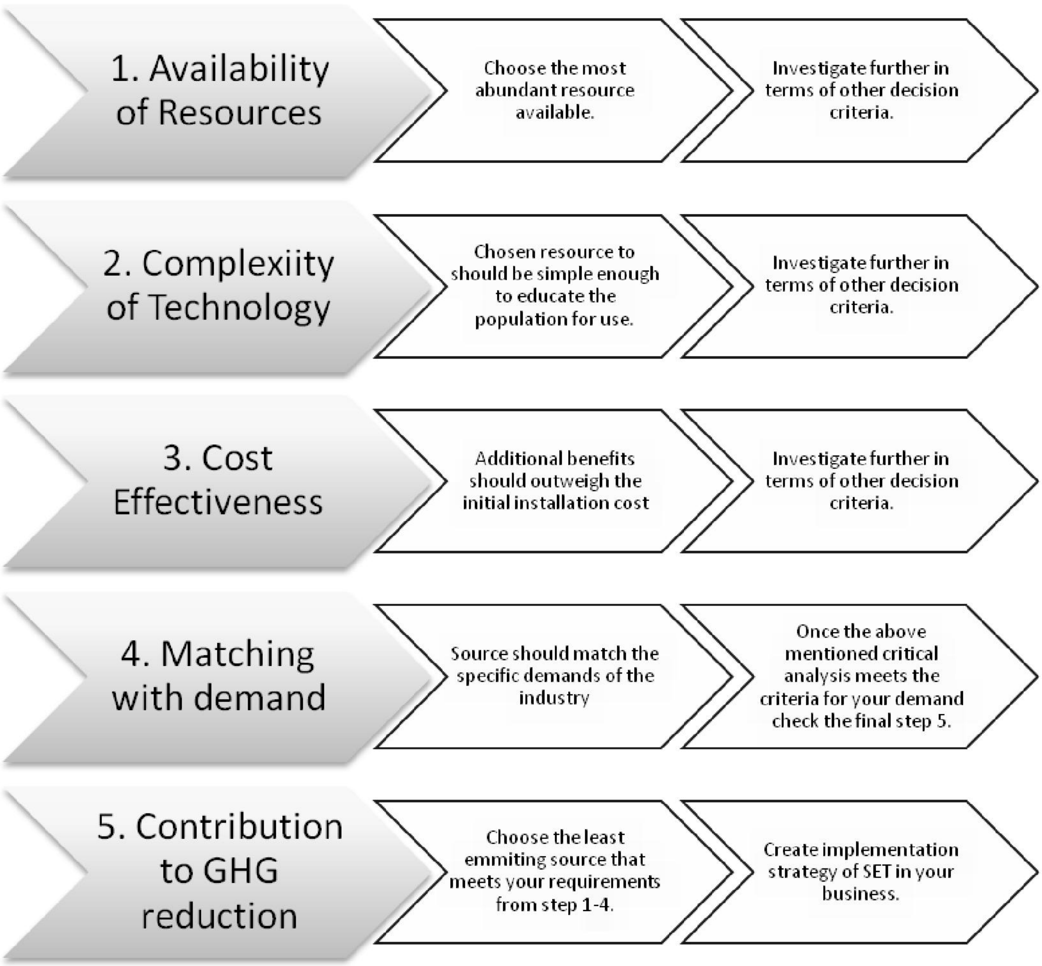
Table-I: Electricity Consumption in Fiji by Sector in 2007.

Sector	*Quantity(Kwh)*	*Percentage of Total (%)*	*Value in F$ million*
Industrial	195,133,086	25.4	34.1
Commercial	332,656,989	43.4	68.5
Domestic	239,029,843	31.2	44.2
Other	-	--	0.9
Total	766,819,918	100.0	147.7

Source: Singh, A. (2009). 'The Sustainable Development of Fiji's Energy Infrastructure: A Status Report'. *Pacific Economic Bulletin,* Vol. 24, No. 2, July, p. 143.

Figure 2.1: Steps in Energy Source Choice for Small Businesses in Rural Fiji.



(Source: Developed by the authors based on the hypothesis)